of cooling down was reached, because there was no water to form them; and no life could have existed on the earth until it cooled down to the latter temperature.

Thus we find in the Arctic regions, the following successive temperatures:—

1.—212° F.	... ...	Boiling water.
2.—122° F.	... ...	Coagulation of albumen.
3.— 68° F.	... ...	Triassic and jurassic periods. (Climate of Gulf of Mexico.)
4.— 48° F.	... ...	Miocene tertiary period. (Climate of Lombardy.)
5.— 32° F.	... ...	(Climate of Labrador.)
6.— 0° F.	... ...	Present climate.

The interval between the first and second corresponds to the azoic rocks; that between the second and third to the palæozoic rocks; and that between the third and fourth to the neozoic rocks. Now, although we do not know the coefficient that fixes the rate of cooling of the hot earth suspended in cold space, we know the law of such cooling, and can compare, by calculation, the proportions of the foregoing intervals of time with each other.

When this calculation is made we obtain:—

Azoic time... ...	(212°–122°)	... ...	33·0 per cent.
Palæozoic time ...	(122°– 68°)	... ...	41·0 ,,
Neozoic time ...	(68°– 48°)	... ...	26·0 ,,
			100·0 ,,

In my former note, iii. p. 545,[1] I have given a table of the approximate thicknesses of the several strata in Europe. That table was prepared, with the assistance of the late Prof. Phillips, many years ago, and is not as complete as it might be. I therefore sought the assistance of Prof. Edward Hull, Director of the Geological Survey of Ireland, and with his help I have constructed an improved table.

Converting the maximum thicknesses recorded in that table into percentages, and comparing them with the percentages of time found from the theory of a cooling globe, we find—

Scale of Geological Time.

Period.	From Theory of Cooling Globe.	From Maximum Thickness of Strata.
Azoic	33·0 per cent.	34·3 per cent.
Palæozoic	41·0 ,,	42·5 ,,
Neozoic	26·0 ,,	23·2 ,,
Total ...	100·0 ,,	100·0 ,,

The agreement between these figures, derived from entirely independent sources, is remarkable, and tends to justify the principle held by many geologists, that—

The proper relative measure of geological periods is the maximum thickness of the strata formed during those periods.

This is equivalent to supposing the rate of deposition of strata to have been constant during the period contained in the table, which is probable enough on other grounds; for, although the rock-making forces were greater when the heat was greater, it must be remembered that the land surfaces to be denuded were smaller, and that the sea bottoms, on which the *débris* was to be spread, were also greater. The calculation founded on the theory of the cooling globe cannot with safety be carried down to near the point of equilibrium temperature, which is the Fahrenheit zero (for the Arctic regions under consideration); but we may, without risk, extend the calculation from 48° F. to 32° F.; that is, we may estimate the interval of time from the miocene tertiary epoch, when the Parry Islands and Northern Greenland enjoyed a Lombardic climate, to the epoch (probably long past) when those districts suffered a climate like that of Labrador, but better than that they now have.

The result of the calculation, when reduced to the same scale as that used in the table, is 32 per cent., a result, the importance of which will be better seen by the following propositions which flow from it:—

1. *A greater interval of time now separates us from the miocene tertiary epoch than that which was occupied in producing all the secondary and tertiary strata, from the triassic to the miocene epoch.*

2. *The enormous interval of time that separates us from the miocene epoch affords ample opportunity for the development of the gigantic mammals, which are commonly supposed to have somewhat suddenly made their appearance on all our continents, and to have disappeared as suddenly.*

All the foregoing facts point to the conclusion that the present condition of the earth's surface is profoundly different from its condition in the geological periods when climates depended chiefly on the internal heat of the earth, and not on that of the sun, as at present.

The following table contains estimates of the number of years required by the several rivers to scrape off one foot from their respective rain-basins, and carry the materials to the sea, where it is spread out on the sea bottoms by ocean currents. The figures are obtained by carefully measuring, at frequent intervals, the total discharge of water and the total weight of mud held in suspension. This weight of mud, reconverted into surface rock, must cover the entire rain-basin to a depth of one foot spread uniformly.

Rates of Denudation of Rain-Basins Lowered One Foot.

Ganges	2,358 years.
Mississippi	6,000 ,,
Hoang Ho	1,464 ,,
Yangtse Kiang	2,700 ,,
Rhone	1,528 ,,
Danube	6,846 ,,
Po	729 ,,
Mean	3,090 ,,

From this table it appears that atmospheric agencies are capable, at present, of lowering the land surfaces at the rate of one foot per 3,000 years; but since the sea bottoms are to the land surfaces in the proportion of 145 to 52, the rate at which (under present circumstances) the sea bottoms are silted up, that is to say, the present rate of formation of strata, *is one foot in* 8,616 *years*. If we admit (which I am by no means willing to do) that the manufacture of strata in geological times proceeded at *ten times* this rate, or at the rate of one foot for every 861·6 years, we have for the whole duration of geological time, down to the miocene tertiary epoch,

$$861 \cdot 6 \times 177{,}200 = 152{,}675{,}000 \text{ years.}^{1}$$

To this must be added at least one-third, as before shown, to bring in the period from the Miocene Tertiary to the time when the Parry Islands and North Greenland had the climate of Labrador.

This gives for the whole duration of geological time a *minimum of two hundred millions of years.*

ACTION OF DRUGS ON THE LIVER[2]

PROF. RUTHERFORD'S paper described the concluding results of the long research undertaken by him on "The Biliary Secretion with Reference to the Actions of Cholagogues." He pointed out the difficulties which had rendered it impossible for physicians to arrive at precise knowledge as to the actions of substances on the liver from observations on the human subject, and the imperative necessity for having recourse to experiments on animals, whereby some of the factors that complicate the case in the uninjured system may be eliminated, and definite knowledge regarding the action of agents on one of the most important organs of the body instituted for the vague guesses of twenty centuries. Several previous investigators had striven by experiments on animals to settle this question, but all had failed owing to the faulty character of the methods employed. By a new and precise method of continuous collection of the bile, and measurement of the amount secreted every fifteen minutes—with a careful elimination of disturbing factors—the whole physiological pharmacology of the liver has been worked out by Prof. Rutherford—as far as it seems at present desirable to proceed. The actions of as many as forty-six substances on the bile-forming function of the liver have been investigated, and results of much importance for rational therapeutics obtained. Some of the

1 *Proc.* R. S., December 20 1877

1 The coefficient 177,200 is the total number of feet of maximum thickness of all the known stratified rocks.

2 Abstract of paper read at the Royal Society of Edinburgh on June 17, by Prof. Wm. Rutherford, F.R.S., Prof. Sir Wyville Thomson (in the absence of Sir Wm. Thomson) in the chair.

substances employed, viz., sodium salicylate, the benzoates, phytolaccin, physostigma, euonymin, sanguinarin, ipecacuan, &c., have not hitherto been known to stimulate the liver; and definite information has now been obtained regarding the influence of a number of other substances whose effects have been hitherto altogether doubtful. He has also proved that if a purgative agent has no direct stimulating power on the liver it diminishes the secretion of bile, and the importance of this fact is indicated. The results of the experiments which were performed on dogs are in complete harmony with every fact that has been perfectly ascertained in the human subject. The experiments with every substance supply a precision of knowledge regarding the effect of that substance on the liver which has not previously existed. In indicating the place for such experiments in medical science, Prof. Rutherford said :—" We all know how excessively complicated the analysis of the effects of drugs becomes when they are administered to a bodily system distorted in its action by the effects of disease. Of necessity the influence of a drug upon a diseased state is the ultimatum of pharmacology; and every experiment upon a healthy bodily system, whether of man or animal, is merely ancillary to experiments with the drug in disease. If we discover that a drug stimulates the healthy liver of a dog, we do not conclude that it must also stimulate the human liver in health, and still less do we conclude that it must have this action in disease. The experiments on the healthy liver of the dog, on the normal and on the abnormal human liver, are three sets of experiments, closely related, but still distinct. The results of any one of the three series cannot be substituted for those of the other two. Each set of facts has its own proper place, and must be carefully kept there. When, therefore, we show by our physiological method of experiment that such a substance as sodium salicylate or sodium benzoate powerfully stimulates the liver of a dog, we do not for a moment say to the clinical observer—You will find that these things act thus in man; but we merely say this: Experiment with these agents on man, and tell us whether or not you find that they stimulate his liver, and tell us also in what diseased states you find the employment of this or of that substance most advantageous. The clinical experimentalist has a far more difficult task to discharge than the physiological investigator, and he urgently requires all the assistance that physiological methods can render him; and the more so because it is now admitted by all competent thinkers that the actions of medicinal agents in diseased conditions cannot be rightly understood unless we also know their effects in a healthy condition of the bodily system." He further showed that although therapeutics can never be brought within the sphere of exact science, it is nevertheless very urgently our present business not to fold our hands in a despairing nihilism, but to search for every fact that can throw light on the function of every bodily organ, the nature of its diseased conditions, and the manner in which it is influenced by medicinal agents in its normal and abnormal states; and all we desire is that those who don't comprehend our methods of procedure, although they are ever ready and eager to profit by its results, will, instead of throwing obstacles in our way, leave us to do what we can to alleviate not only the sufferings of human beings, but also those of animals.

At the conclusion of the paper Sir Robert Christison characterised the professor's communication as of the greatest importance, and as one which would hand his name down to a very distant future. The professor deserved the commendation of the Society for his courage in going on, in spite of a sentimental opposition, with his researches. He thought that the time would come when the public would wake up from the delusion in this regard in which it now was. Sir Wyville Thomson, in intimating the thanks of the Society to Prof. Rutherford, said that, in his opinion, if a man in a public position felt that he had knowledge and nerve sufficient to perform these experiments for lessening the suffering and prolonging the lives of men, even though they should involve a certain amount of suffering to the lower animals, he was not only entitled but was bound to peform them.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, May 16.—"On the Spectra of Metalloids. Spectrum of Oxygen." By Arthur Schuster, Ph.D., F.R.A.S. Communicated by J. Clerk Maxwell, F.R.S., Professor of Experimental Physics in the University of Cambridge.

The many unexplained phenomena attending the passage of electricity through gases will probably for some time to come occupy the attention of experimental physicists. It is desirable that the subject should be approached from as many different sides as possible. One of our most powerful instruments of research is the spectroscope, but before it can be applied to the study in question we have to settle the chemical origin of the different spectra, which we observe in vacuum tubes, and to discuss in what way such spectra are liable to change under different circumstances. I have chosen oxygen as a first subject of investigation. Though Plücker and Wüllner have, as far as their experiments went, accurately described the phenomena seen in oxygen tubes, the following contains much that is new, and will put some of the older facts on a firmer basis.

As some of the facts brought to light by the investigation bear directly on the question of double spectra, our knowledge on that point must be briefly referred to. We divide all known spectra into three orders—continuous spectra, channelled space spectra, and line spectra. With regard to continuous spectra, it is shown that the older statement which limited them to liquid and solid bodies is no longer tenable. Most gases give continuous spectra long before they condense. Two theories of continuous spectra are noticed. The one considers that the vibrations of a molecule always tend to take place in a fixed period, but that the impacts of other molecules may, when the pressure is great or in liquid and solid bodies, prevent complete oscillations taking place, and thus produce a continuous spectrum. The other theory considers that, when a gas condenses, molecular combinations take place, which make the molecular structure more complicated, and may produce channelled space spectra or continuous spectra. According to the latter theory such molecular combinations are possible before the gas condenses, and thus the state of aggregation of the gas only indirectly affects the spectrum. The latter theory seems to be more consistent with experiment than the former one. For instance, it is shown that oxygen gives a continuous spectrum at the lowest temperature at which it is luminous. If the temperature be raised, the continuous spectrum is replaced by a line spectrum. This seems to be inexplicable by theory of molecular impacts.

The chief difficulty in the way of a complete investigation of the spectrum of oxygen consists in the great disturbing influence of the presence of even a small quantity of any carbon compound. Amongst a great many oxygen tubes which were filled by various makers I only found one, which showed the spectrum of pure oxygen; all the others gave a spectrum of carbonic oxide. It is therefore necessary in filling oxygen tubes to avoid all greased joints and all india-rubber tubings. I have used a Sprengel air-pump which communicated with the vacuum tube by means of a ball and socket joint. The joint was kept air-tight solely by means of strong sulphuric acid. The vacuum tube was fused directly to the ball of the joint. To one end of the vacuum tube a piece of hard glass tubing had been fused. This was filled with different substances which, on heating, gave off pure oxygen. The oxygen, therefore, came only into contact with glass, mercury, and sulphuric acid, and the metal of the electrode. Permanganate of potash, oxide of mercury, and chlorate of potash, were used in turn, to prepare the oxygen, but no effect was observed which could be traced to the substance used. The effect of the electrodes was eliminated by varying the metals. Aluminium, platinum, silver, brass, and iridium were used as electrodes. Any possible effect of the glass was eliminated by finally repeating all experiments in a glass receiver six inches in diameter, so that no part of the spark came nearer than 2½ inches to the glass. In this way it is believed all possibility of error due to the presence of any possible impurities was avoided.

Four different spectra of oxygen must be distinguished. At the lowest temperature at which oxygen becomes luminous it gives a continuous spectrum. As the temperature is gradually raised the continuous spectrum is successively transformed into two distinct line spectra, which I call respectively the compound line spectrum and the elementary line spectrum. It is one of the principal objects of this paper to show that these two line spectra which have been much mixed up together have a separate existence. The generation of one always involves the destruction of the other. The fourth spectrum is that which is always seen in vacuum tubes at the negative pole.

The Continuous Spectrum.—The following facts prove the statement that at the lowest temperature at which oxygen is luminous it shows a continuous spectrum.